Rec'd PCT/PTO 26 SEP 2005
10/526410



# DESCRIPTION

## Liquid crystal display device having sound output function and the like and an electronic device using the same

## TECHNICAL FIELD

The present invention relates to a liquid crystal display device used as a liquid crystal display module in various kinds of electronic devices, and relates more particularly to adding a sound output function to such a liquid crystal display device.

## BACKGROUND ART

Liquid crystal display (LCD) devices are typically used as the display device in cell phones, PDAs (personal digital assistants), and other portable devices. Rising demand for greater display capacity in these LCD devices has meant that the LCD screen area has also tended to grow. Furthermore, as screen size has increased so has demand for size and weight reductions in the portable devices in which the LCD devices are used. As a result, providing sufficient space for a speaker and receiver (microphone) in a portable device also requiring a function for sound input and output has become increasingly difficult.

A transparent speaker made from a piezoelectric diaphragm composed of a transparent piezoelectric element and a transparent electrode, and a frame supporting the periphery of the diaphragm, has thus been proposed (see, for example, Japanese Unexamined Patent Appl. Pub. 2000-152385). A speaker function can thus be achieved without obstructing the LCD by applying this transparent speaker over the front of the LCD panel.

A panel speaker composed of a diaphragm that also functions as an optical filter in the LCD device, and an exciter affixed to the back of the four edge portions of this diaphragm, has also been proposed (see, for example, Japanese Unexamined Patent Appl. Pub. 2001-189978). This panel speaker

uses the same space for both the display and sound generation, and thus offers the advantage of not requiring excessive space to provide both a display and audio output.

A loudspeaker drive unit has also been achieved by driving transparent panel-shaped members disposed in front of the display surface of a LCD device, for example, with a vibration exciter disposed at the edges or peripheral portion of the panel member. (See Japanese Examined Patent Pub. 2002-533957, for example.)

A problem with these methods of the foregoing prior art is that the thickness of the device in which the display device is used increases because the speaker is rendered over the display surface. Furthermore, because the exciter (vibration source) is disposed around the edges of the LCD panel in the foregoing panel speaker, the exciter competes for space with other components similarly disposed in said peripheral area. LCD devices commonly use a light emitting diode (LED) or other light source, and installation space for this light source competes with installation space for the exciter of the foregoing panel speaker in the edge portions of the LCD panel. Using a panel speaker as described above therefore does not necessarily yield the expected space savings. As a result, the external size of the LCD device increases when a sound output function is added, and this is particularly a problem with portable devices. Furthermore, because the prior art as described above requires rendering a separate panel member used as the speaker diaphragm in front of the display, the thickness of the frame (casing) in which the LCD device is housed is increased, and adding a sound output function invites a drop in transmittance and thus degrades the quality of displayed images.

An object of the present invention is therefore to provide a liquid crystal display device having a light source to which a sound output function and the like can be added while suppressing an increase in external size and a decrease in display quality.

DISCLOSURE OF THE INVENTION

A first aspect of the present invention is a liquid crystal display device having a liquid crystal panel including a first substrate, a second substrate, and a liquid crystal layer disposed between the first substrate and second substrate, and a light guide plate disposed on the side of the second substrate that is not in contact with the liquid crystal layer, said liquid crystal display device comprising:

a connection terminal part disposed to an edge portion of the second substrate on the side thereof in contact with the liquid crystal layer;

an excitation source disposed to an edge portion of the second substrate on the side thereof not in contact with the liquid crystal layer at a position opposite the connection terminal part; and

a light source disposed near at least one side of the light guide plate other than the side of the light guide plate closest to the excitation source so that light enters the light guide plate from the side to which the light source is disposed;

wherein the excitation source produces sound by causing the second substrate to flexurally vibrate according to an externally supplied sound signal.

This first aspect of the present invention suppresses an increase in the external size of a liquid crystal display device resulting from adding a sound output function (speaker function) to the liquid crystal display device because the second substrate of the liquid crystal panel is used as the diaphragm for sound output, the excitation source is disposed to an edge portion of the second substrate on the opposite side as the connector part, that is, in an area where space is available, and the light source is disposed near at least one side of the light guide plate other than the side of the light guide plate closest to the excitation source. A drop in display quality resulting from adding a sound output function can also be avoided because the second substrate part of the liquid

crystal panel is used as the diaphragm and separately providing a diaphragm for sound output in front of the display unit is not necessary.

A second aspect of the present invention is characterized by the light source in the first aspect of the invention being disposed opposite the excitation source with the light guide plate therebetween.

This second aspect of the present invention suppresses an increase in the external size of the liquid crystal display device resulting from adding an excitation source because the light source is disposed opposite the excitation source with the light guide plate therebetween.

A third aspect of the present invention is characterized by the light source in the first aspect of the invention being disposed near a side of the light guide plate that is adjacent to the side closest to the excitation source.

With this third aspect of the present invention the light source is disposed near a side of the light guide plate that is adjacent to the side of the light guide plate closest to the excitation source. As a result, the light source can be disposed by effectively using a non-display area in an edge portion of the second substrate when an IC chip (bare chip) driver circuit is mounted to an edge portion of the second substrate in the area on the opposite side as the light source. As a result, an increase in the external size due to adding a sound output function to the liquid crystal display device can be suppressed.

A fourth aspect of the present invention is a liquid crystal display device having a liquid crystal panel including a first substrate, a second substrate, and a liquid crystal layer disposed between the first substrate and second substrate, and a light guide plate disposed on the side of the first substrate or second substrate that is not in contact with the liquid crystal layer, said liquid crystal display device comprising:

a light source disposed near a predetermined side of the light guide plate so that light enters the light guide plate from said predetermined side; and

an excitation source disposed to an edge portion of the first or second substrate near a side of the light guide plate other than said predetermined side;

wherein the excitation source produces sound by causing the first or second substrate to flexurally vibrate according to an externally supplied sound signal.

This fourth aspect of the present invention suppresses an increase in the external size of the liquid crystal display device resulting from adding a sound output function because the first or second substrate of the liquid crystal panel is used as the diaphragm for sound output, and the light source and the excitation source are disposed to an edge portion of the first or second substrate so that the light source and excitation source do not compete for installation space.

A fifth aspect of the present invention is characterized by the light source in the fourth aspect of the invention being disposed opposite the excitation source with the light guide plate therebetween.

This fifth aspect of the present invention suppresses an increase in the external size of the liquid crystal display device resulting from adding an excitation source because the light source is disposed opposite the excitation source with the light guide plate therebetween.

A sixth aspect of the present invention is characterized by the light source in the fourth aspect of the invention being disposed near a side of the light guide plate that is adjacent to the side closest to the excitation source.

With this sixth aspect of the present invention the light source can be disposed by effectively using a non-display area in an edge portion of the first or second substrate when an IC chip (bare chip) driver circuit is mounted to an edge portion of the first or second substrate in the area thereof on the opposite side as the light source. As a result, an increase in

the external size due to adding a sound output function to the liquid crystal display device can be suppressed.

A seventh aspect of the present invention is characterized by any of the first to sixth aspects of the invention further comprising a frame for housing the liquid crystal panel and light guide plate;

wherein the excitation source is disposed in contact with the frame or bonded to the frame, and causes the frame to flexurally vibrate according to the sound signal.

This seventh aspect of the invention achieves high output volume because the excitation source causes the frame to flexurally vibrate in addition to the first or second substrate.

An eighth aspect of the present invention is characterized by any of the first to sixth aspects of the invention wherein:

the first and second substrates comprise a glass plate of which one side is in contact with the liquid crystal layer, and

a sheet of optical material disposed to cover a predetermined effective display area on the other side of the glass plate; and

the excitation source is disposed in contact with the glass plate at an edge portion thereof in an area outside the effective display area on said other side of the first or second substrate, and directly causes the glass plate to flexurally vibrate according to said sound signal.

This eighth aspect of the invention enables the sound energy produced by the mechanical vibrations generated by the excitation source to propagate efficiently because the excitation source directly causes the glass plate that is part of the first or second substrate to flexurally vibrate according to a sound signal.

A ninth aspect of the present invention is characterized by any of the first to third aspects of the invention wherein the excitation source is disposed to an edge portion of the second substrate on the side thereof not in contact with the liquid crystal layer at a position corresponding to a middle portion of the connection terminal part.

Sound energy produced by the mechanical vibrations generated by the excitation source is transmitted uniformly in the liquid crystal panel with this ninth aspect of the present invention because the excitation source is disposed to an edge portion on the outside surface of the second substrate at a position corresponding to the middle of the connection terminal part.

A tenth aspect of the invention is the ninth aspect of the invention further comprising:

a frame for housing the liquid crystal panel and light guide plate; and

a chassis fit to an inside surface on the back side of the frame for supporting the liquid crystal panel;

wherein the liquid crystal panel is housed in the frame so that the first substrate is positioned on the front side and the second substrate is positioned on the back side; and

the chassis has a thick-walled portion formed in corner areas at both end parts of the edge portion on the side of the second substrate not in contact with the liquid crystal layer.

This tenth aspect of the invention can support and secure the liquid crystal panel stably inside the frame, and the thick-walled parts stabilize the fit of the chassis to the frame, because the thick-walled parts formed in the corners of the chassis support the liquid crystal panel.

An eleventh aspect of the present invention is any of the first to sixth aspects of the invention further comprising:

at least one other excitation source in addition to said excitation source;

wherein said other excitation source causes the first or second substrate to flexurally vibrate according to an externally supplied sound signal.

This eleventh aspect of the invention can produce a high sound volume because there is a plurality of excitation sources and the same sound signal is input to each of the excitation sources. In addition, a three-dimensional sound can be achieved or the sound output position can be controlled in the liquid

crystal panel by inputting different sound signals (sound signals from different signal sources, or sound signals of different phase and amplitude from the same signal source) to the excitation sources.

A twelfth aspect of the present invention is any of the first to sixth aspects of the invention further comprising:

a pickup unit for converting vibrations of the first or second substrate to electric signals when external sound waves cause the first or second substrate to vibrate;

wherein said pickup unit is disposed instead of the excitation source in the position of the excitation source, or is disposed near said excitation source together with said excitation source.

By providing a pickup unit instead of an excitation source, this twelfth aspect of the invention achieves a sound input function (microphone function) in the liquid crystal display device while suppressing an increase in external size. Furthermore, both a sound input function and a sound output function can be achieved in a liquid crystal display device while suppressing an increase in the external size by disposing a pickup unit near the excitation source in conjunction with the excitation source.

A thirteenth aspect of the invention is an electronic device having a liquid crystal display device according to the eleventh aspect of the invention, comprising:

a data processing means for receiving combined data containing image data representing an image to be displayed on the liquid crystal panel and position data denoting a sound output position in the image, and separating and outputting the image data and position data; and

a signal processing means for controlling the phase and amplitude of sound signals to be input to the plurality of excitation sources including said other excitation source based on the position data output from the data processing means so that sound is output from a position in the first or second

substrate corresponding to the sound output position in the image.

This thirteenth aspect of the invention can thus control the position from which sound is produced from the liquid crystal panel as a result of the signal processing means controlling the phase and amplitude of the sound signals to be input to the plurality of excitation sources.

A fourteenth aspect of the invention is an electronic device having a liquid crystal display device according to the eleventh aspect of the invention, comprising:

a data processing means for receiving combined data containing image data representing an image to be displayed on the liquid crystal panel and position data denoting a sound output position in the image, and separating and outputting the image data and position data; and

a signal processing means for controlling the phase and amplitude of sound signals to be input to the plurality of excitation sources including said other excitation source based on the position data output from the data processing means so that sound is output from a position in the first or second substrate corresponding to the sound output position in the image.

By controlling the phase and amplitude of the sound signals to be input to the plurality of excitation sources based on the position data output from the data processing means, this fourteenth aspect of the invention can output sound from the position on the liquid crystal panel corresponding to the position in the image indicated by the position data, and can thus link the image displayed on the liquid crystal panel and the sound emitted from the liquid crystal panel.

A fifteenth aspect of the invention is characterized by comprising a liquid crystal display device according to any of the first to twelfth aspects of the invention.

This fifteenth aspect of the invention thus achieves the same effects as the first to twelfth aspects of the invention.

A sixteenth aspect of the invention is any of the first to sixth aspects of the invention further comprising:

a frame for housing the liquid crystal panel and light guide plate; and

a structural panel disposed between the frame and the liquid crystal panel or the light guide plate so that one side of the structural panel is in contact with the inside surface of the frame;

wherein the excitation source is disposed in contact with the other side of the structural panel, or bonded to said other side, and causes the frame to flexurally vibrate according to the sound signal simultaneously to the liquid crystal panel by way of the intervening structural panel.

This sixteenth aspect of the invention can achieve a high sound output volume because the excitation source causes the structural panel and frame to flexurally vibrate in addition to the substrate according to the sound signal.

A seventeenth aspect of the invention is the sixteenth aspect of the invention wherein the structural panel is located on the display surface side of the liquid crystal panel and comprises a sensor function for functioning as an operating unit.

By providing a structural panel with a sensor function enabling operation as an operating unit, this seventeenth aspect of the invention thus enables an arrangement whereby the liquid crystal display device alone can produce vibrations in the excitation source triggered by a specific operation.

An eighteenth aspect of the invention is the sixteenth aspect of the invention wherein the structural panel is located on the display surface side of the liquid crystal panel and comprises a complementary display.

This eighteenth aspect of the present invention can produce high sound volume because the structural panel can be driven to flexurally vibrate not only where the panel overlaps the display surface of the liquid crystal display device but

also in the part having a display area outside the liquid crystal display area.

A nineteenth aspect of the invention is the seventeenth or eighteenth aspect of the invention wherein the structural panel has a display indicating functions executed by predetermined operations; and

the excitation source receives a signal denoting a vibration pattern corresponding to the predetermined operation from a predetermined signal generating means disposed externally or internally to the liquid crystal display device, and causes the structural panel to flexurally vibrate in a vibration pattern corresponding to the predetermined operation based on said signal.

The excitation source in this nineteenth aspect of the invention can selectively generate specific vibration patterns predefined for specific operations because the structural panel displays functions that can be executed by means of specific predefined operations.

A twentieth aspect of the invention is an electronic device comprising a liquid crystal display device according to any of the sixteenth to nineteenth aspects of the invention.

This twentieth aspect of the invention achieves the same effects as the sixteenth to nineteenth aspects of the invention.

A twenty-first aspect of the invention is a liquid crystal display device having a liquid crystal panel including a first substrate, a second substrate, and a liquid crystal layer disposed between the first substrate and second substrate, a light guide plate disposed on the side of the second substrate that is not in contact with the liquid crystal layer, and a frame for housing the liquid crystal panel and light guide plate, said liquid crystal display device comprising:

a connection terminal part disposed to an edge portion on the side of the second substrate in contact with the liquid crystal layer;

an excitation source disposed bonded to the inside surface of the frame at a position facing an edge portion of the second

substrate on the surface thereof not in contact with the liquid crystal layer at a position on the opposite side as the connection terminal part so that vibration is not transmitted directly to said opposite-side edge portion; and

a light source held in the frame and disposed near at least one side of the light guide plate other than the side of the light guide plate closest to the excitation source so that light enters the light guide plate from the at least one side to which the light source is disposed;

wherein the excitation source produces sound by causing the frame to flexurally vibrate according to an externally supplied sound signal.

This twenty-first aspect of the invention can suppress an increase in the external size of the liquid crystal display device due to the addition of a sound output function (speaker function) because the frame of the liquid crystal display device (liquid crystal display module) is used as the diaphragm for producing sound, the excitation source is disposed to an edge portion of the second substrate in an area on the opposite side as the connection terminal part, that is, in an area where space is available, and the light source is disposed to at least one side of the light guide plate other than the side of the light guide plate that is closest to the excitation source. Furthermore, vibrations from the excitation source are emitted primarily from the frame of the liquid crystal display device, an internal space inside the device comprising the liquid crystal display device as a LCD module, or the frame or other part of the device other than the display surface. As a result, if this LCD module is used in a device having a touch sensor rendered over the display panel and small button icons or smaller points on the display are selected using a stylus for hyperlinking operations, to specify the location for such data processing operations as drawing lines, enlarging, or reducing an image in a computer-aided drawing program, to make gestures, or to make menu selections, for example, sound vibrations will not interfere with such pointing operations. A liquid crystal

display device (liquid crystal display module) according to the present invention can thus also be used in applications requiring the ability to point to a position precisely and accurately.

A twenty-second aspect of the invention is the twenty-first aspect of the invention wherein the excitation source is disposed with a space between the excitation source and the second substrate to avoid contact with the second substrate at the expected vibration amplitude of the excitation source.

By providing the minimum space allowing the expected sound vibrations between the excitation source and liquid crystal panel with the twenty-second aspect of the invention, the transmission of vibrations from the excitation source to the liquid crystal panel can be substantially suppressed without increasing the thickness of the LCD module.

A twenty-third aspect of the invention is the twenty-first aspect of the invention further comprising a buffer material between the excitation source and the second substrate.

By thus providing a buffer material between the excitation source and the liquid crystal panel (second substrate), this twenty-third aspect of the invention improves the resistance of the excitation source to external stresses other than the sound vibrations produced by the excitation source, and can suppress or eliminate the transmission of vibration to the liquid crystal panel from the excitation source without increasing the thickness of the LCD module.

A twenty-fourth aspect of the invention is any of the twenty-first to twenty-third aspects of the invention further comprising a buffer material between the liquid crystal panel and frame.

In addition to suppressing or eliminating the direct transmission of vibration from the excitation source to the liquid crystal panel, the buffer material disposed in this twenty-fourth aspect of the invention between the frame of the LCD module and the liquid crystal panel can suppress or eliminate the transmission of vibration to the liquid crystal

panel from the frame that functions as the primary diaphragm driven by the excitation source.

A twenty-fifth aspect of the invention is any of the twenty-first to twenty-fourth aspects of the invention further comprising a buffer material between the liquid crystal panel and light guide plate.

With this twenty-fifth aspect of the invention the buffer material disposed between the light guide plate and liquid crystal panel supports the liquid crystal panel freely and reduces the inertial mass, and thereby efficiently suppresses or eliminates the transmission of vibrations from other parts of the LCD module to the liquid crystal panel.

A twenty-sixth aspect of the invention is any of the twenty-first to twenty-fourth aspects of the invention further comprising a buffer material between the light guide plate and frame.

The buffer material thus disposed between the frame of the LCD module and the light guide plate in this twenty-sixth aspect of the invention freely supports both the light guide plate and liquid crystal panel in contact with each other, prevents vibrations from changing the light path from the light source, and suppresses or eliminates the transmission of vibrations from the frame.

A twenty-seventh aspect of the invention is any of the twenty-first to twenty-sixth aspects of the invention wherein the light source is disposed opposite the excitation source with the light guide plate therebetween.

This twenty-seventh aspect of the invention can suppress an increase in the external size of a liquid crystal display device resulting from adding an excitation source thereto even when the excitation source uses primarily the frame as the diaphragm because the light source is located opposite the excitation source with the light guide plate therebetween.

A twenty-eighth aspect of the invention is any of the twenty-first to twenty-sixth aspects of the invention wherein the light source is disposed near a side of the light guide

plate that is adjacent to the side closest to the excitation source.

This twenty-eighth aspect of the invention thus disposes the light source near a side of the light guide plate that is adjacent to the side of the light guide plate closest to the excitation source even in an arrangement in which the excitation source uses primarily the frame as the diaphragm. Therefore, in an arrangement in which an IC chip (bare chip) driver circuit is mounted to an edge portion of the second substrate in the area on the opposite side as the light source, the light source can be disposed by effectively using a non-display area in the edge portion of the second substrate. As a result, an increase in the external size of the liquid crystal display device caused by adding a sound output function can be suppressed.

A twenty-ninth aspect of the invention is any of the twenty-first to twenty-eighth aspects of the invention wherein:

the first and second substrates comprise a glass plate of which one side is in contact with the liquid crystal layer, and

a sheet of optical material disposed to cover a predetermined effective display area on the other side of the glass plate; and

the excitation source is disposed in contact with the frame at an edge portion on said other side of the first or second substrate in an area outside the effective display area, and causes the frame to flexurally vibrate according to said sound signal.

This twenty-ninth aspect of the invention enables sound energy resulting from the mechanical vibrations generated by the excitation source to propagate efficiently even in an arrangement in which the excitation source uses primarily the frame as a diaphragm because the excitation source directly causes the frame to flexurally vibrate according to the sound signal.

A thirtieth aspect of the invention is any of the twenty-first to twenty-ninth aspects of the invention wherein the

excitation source is disposed to an edge portion of the second substrate on the side thereof not in contact with the liquid crystal layer at a position corresponding to a middle portion of the connection terminal part.

This thirtieth aspect of the invention uniformly transmits sound energy produced by the mechanical vibrations generated by the excitation source to the LCD module frame even in an arrangement in which the excitation source uses primarily the frame as a diaphragm because the excitation source is disposed to an edge portion on the outside surface of the second substrate at a position corresponding to the middle of the connection terminal part.

A thirty-first aspect of the invention is the thirtieth aspect of the invention further comprising:

a chassis fit to an inside surface on the back side of the frame for supporting the liquid crystal panel;

wherein the liquid crystal panel is housed in the frame so that the first substrate is positioned on the front side and the second substrate is positioned on the back side; and

the chassis has a thick-walled portion formed in corner areas at both end parts of the edge portion on the side of the second substrate not in contact with the liquid crystal layer.

This thirty-first aspect of the invention can stably support and secure the liquid crystal panel in the frame and the thick-walled portions stabilize the fit of the chassis and the frame even in an arrangement in which the excitation source uses primarily the frame as a diaphragm because the thick-walled portions formed in the corners of the chassis support the liquid crystal panel.

A thirty-second aspect of the invention is the thirty-first aspect of the invention further comprising a buffer material between the liquid crystal panel and the chassis.

With this thirty-second aspect of the invention the buffer material disposed between the chassis and liquid crystal panel supports the liquid crystal panel freely and minimizes the inertial mass, and thereby efficiently suppresses or eliminates

the transmission of vibrations from other parts of the LCD module to the liquid crystal panel.

A thirty-third aspect of the invention is the thirty-first aspect of the invention further comprising a buffer material between the chassis and the frame.

The buffer material thus disposed between the frame of the LCD module and the chassis in this thirty-third aspect of the invention freely supports both the chassis and the liquid crystal panel in contact with each other, and suppresses or eliminates the transmission of vibrations through the frame to the liquid crystal panel while the chassis continues to securely hold the liquid crystal panel.

A thirty-fourth aspect of the invention is any of the twenty-first to thirty-third aspects of the invention further comprising:

at least one other excitation source in addition to said excitation source;

wherein said other excitation source causes the frame to flexurally vibrate according to an externally supplied sound signal.

By thus providing a plurality of excitation sources, this thirty-fourth aspect of the invention can produce high sound volume even in an arrangement in which the excitation source uses primarily the frame as a diaphragm by applying the same sound signal to plurality of excitation sources.

A thirty-fifth aspect of the invention is an electronic device comprising a liquid crystal display device according to any of the twenty-first to thirty-fourth aspects of the invention.

This thirty-fifth aspect of the invention achieves the same effects as the twenty-first to thirty-fourth aspects of the invention.

## BRIEF DESCRIPTION OF DRAWINGS

Fig. 1 is a side view showing a liquid crystal panel and associated parts in a LCD device according to a first embodiment of the present invention.

Fig. 2 is a bottom view from the back side of the LC panel in the first embodiment.

Fig. 3 is a side view showing the liquid crystal panel and associated parts in a LCD device according to the prior art.

Fig. 4 is a detailed side view showing the arrangement of a LC panel in the first embodiment.

Fig. 5 is a longitudinal section view of a LCD device according to the first embodiment.

Fig. 6 is a side section view through line A-A in Fig. 5.

Fig. 7 is a side view showing the liquid crystal panel and associated parts in a LCD device according to a second embodiment of the present invention.

Fig. 8 is a bottom view showing the liquid crystal panel and associated parts in the second embodiment.

Fig. 9 is a bottom view showing another arrangement of the liquid crystal panel and associated parts in the second embodiment.

Fig. 10 is a longitudinal section view of a LCD device according to a third embodiment of the present invention.

Fig. 11 is a side view showing a liquid crystal panel and associated parts in a LCD device according to a fourth embodiment of the present invention.

Fig. 12 is a bottom view showing the liquid crystal panel and associated parts in the fourth embodiment.

Fig. 13 is a side view showing a liquid crystal panel and associated parts in a LCD device used in an electronic device according to a fifth embodiment of the present invention.

Fig. 14 is a bottom view showing the liquid crystal panel and associated parts in the fifth embodiment.

Fig. 15 is a function block diagram showing a main components of the electronic device according to the fifth embodiment.

Fig. 16 is a plan view showing a LC panel in a LCD device used in an electronic device according to a sixth embodiment of the invention.

Fig. 17 is a function block diagram showing a main components of the electronic device according to the sixth embodiment.

Fig. 18 is a side view showing a liquid crystal panel and associated parts in the LCD device according to the seventh embodiment.

Fig. 19 is a side view showing another arrangement of the LC panel and associated parts in the LCD device according to the seventh embodiment.

Fig. 20 is a longitudinal section view of a LCD device according to an eighth embodiment of the present invention.

Fig. 21 is a plan view showing the appearance of the electronic device having the LCD device according to the eighth embodiment.

Fig. 22 is a longitudinal section view of a LCD device according to a ninth embodiment of the present invention.

Fig. 23 is a longitudinal section view showing a second, alternative, arrangement of the LCD device according to the ninth embodiment.

Fig. 24 is a longitudinal section view showing a third, further alternative, arrangement of the LCD device according to the ninth embodiment.

Fig. 25 is a longitudinal section view showing a fourth, further alternative, arrangement of the LCD device according to the ninth embodiment.

Fig. 26 is a longitudinal section view showing a fifth, further alternative, arrangement of the LCD device according to the ninth embodiment.

Fig. 27 is a longitudinal section view showing a sixth, further alternative, arrangement of the LCD device according to the ninth embodiment.

Fig. 28 is a bottom view showing the liquid crystal panel and associated parts in a LCD device according to a tenth embodiment of the present invention.

Fig. 29 is a bottom view showing the liquid crystal panel and associated parts in a LCD device according to an eleventh embodiment of the present invention.

BEST MODE FOR CARRYING OUT THE INVENTION

Preferred embodiments of the present invention are described in detail below with reference to the accompanying drawings.

<1. First embodiment>

Fig. 1 is a side view showing the liquid crystal panel and the light guide plate, light source, and other parts associated therewith in a liquid crystal display device according to a first embodiment of the present invention, and Fig. 2 is a bottom view of the LC panel shown in Fig. 1 as seen from the back side thereof. This LCD device 201 is used as a liquid crystal display module in a portable electronic device such as a cell phone or PDA, and has a sound output function, that is, a speaker function, in addition to an image display function.

A liquid crystal panel 101 in this embodiment of the present invention has a first substrate 11 and a second substrate 12 as a pair of opposing substrates. These substrates are fixed with a predetermined gap therebetween (typically several ten microns). This gap is filled with a liquid crystal material, forming a liquid crystal layer. This LC panel 101 is transparent or semi-transparent. For example, each of substrates 11, 12 is composed of a glass plate in contact with the liquid crystal layer on one side and a polarizer laminated to the other side of this glass plate (on the side not in contact with the liquid crystal layer). A circuit including a plurality of mutually parallel scanning electrodes, a plurality of signal electrodes perpendicularly intersecting the plurality of scanning electrodes, and a pixel electrode and thin-film transistor (TFT) disposed to each node of the intersections of

the multiple scanning electrodes and the multiple signal electrodes is formed using a polycrystalline silicon thin film on one of these substrates 11, 12, specifically on the side of the second substrate 12 in contact with the liquid crystal layer in this embodiment of the invention. A flexible printed circuit ("FPC" below) 16 is connected to the edge portion of this second substrate 12. The signals required to display images are supplied by this FPC 16 to the LC panel 101. A common electrode is disposed as the opposite electrode over the entire surface of the first substrate 11 on the side thereof in contact with the liquid crystal layer, and an appropriate voltage is applied to this common electrode. A voltage equivalent to the potential difference between the pixel electrode and common electrode is thus applied to the liquid crystal layer, and the light transmittance of the liquid crystal layer is controlled by this applied voltage. As a result, a desired image can be displayed by the LC panel 101 based on the signals supplied from this FPC 16.

The drive signals applied to the scanning electrodes and signal electrodes can be supplied by the FPC 16 to the LC panel 101, but the drive circuit for generating these drive signals is preferably rendered on the second substrate 12 integrally with the TFT, for example. In this embodiment, therefore, this drive circuit is formed integrally with the TFT on the second substrate 12 by means of a polycrystalline silicon thin film.

A light guide plate 20 is disposed behind the image display surface of this LC panel 101 on the side of the second substrate 12 not in contact with the liquid crystal layer, and an LED 22 is disposed as the light source near the side of the light guide plate 20. Light emitted from the LED 22 is thus guided from the side through the light guide plate 20, travels through the light guide plate 20, and is emitted in the direction of the first substrate 11, that is, to the image display side, thereby illuminating the liquid crystal layer inside the LC panel 101. An image is displayed on the LC panel 101 by controlling the light transmittance of the liquid

crystal layer as described above so that the light transmittance varies according to the drive signals. Note that the light source used for illuminating the LC panel 101 shall not be limited to an LED, and a cold cathode tube could be used instead of an LED, for example.

The LED 22 used as the light source is conventionally disposed on the back side of the second substrate 12 in the same area as where the FPC 16 is connected as shown in Fig. 3, that is, at the edge portion on the side of the second substrate 12 not contacting the liquid crystal layer in substantially the same area as the FPC 16 connector. However, a LCD device according to this embodiment of the invention has an internal excitation source 30 for converting a sound signal (electrical signal) to mechanical vibrations in order to achieve a sound output function. Sound is then output from this LC panel 101 by driving the excitation source 30 to cause the second substrate 12 of the LC panel 101 to vibrate. This excitation source 30 could be manufactured using a piezoelectric element made from quartz, Rochelle salt crystals, or a ceramic thin plate, for example.

As described above, a sound output function (speaker function) is achieved by using an excitation source 30 to make the second substrate 12 vibrate. The resulting problem is that adding this excitation source 30 to a conventional arrangement such as shown in Fig. 3 leads to an increase in the external size of the portable electronic device in which the LCD device is used (such as a cell phone or PDA). The present embodiment, therefore, disposes the excitation source 30 on the opposite side of the second substrate 12 of the LC panel 101 as the connector part of the FPC 16, that is, in the edge portion on the surface of the second substrate 12 not in contact with the liquid crystal layer (the "outside surface" below) in the area substantially opposite the connector part of the FPC 16. In addition, the LED 22 light source is disposed on the opposite side of the light guide plate 20 as the side near where the LED 22 is located in the conventional arrangement shown in Fig. 3.

The excitation source 30 and LED 22 are thus disposed with the light guide plate 20 therebetween in this embodiment of the invention. Because the area needed to provide the LED 22 is sufficiently small relative to the area on the back side of the second substrate 12 opposite the connector part of the FPC 16, the external size can be expected to not increase even if the installation space needed for the LED 22 is moved to a different edge area than the edge area opposite the connector part. Note further that in the prior art example shown in Fig. 3 the LED 22 is electrically connected via an FPC 24 disposed parallel to the back or side of the FPC 16, but the LED 22 in this embodiment of the invention is electrically connected by way of an FPC 24 disposed on or in the neighborhood of the back or side of the edge portion of the second substrate 12 as shown in Fig. 1 and Fig. 2.

By thus disposing the excitation source 30, which is larger than the LED 22, in the area on the back of the second substrate 12 opposite the connector part of the FPC 16, that is, in the area where space is available, the overall increase in the external size of the LCD device 201 resulting from addition of the excitation source 30 can be suppressed.

Fig. 4 is a side view showing one detailed example of the arrangement of the LC panel 101 in this embodiment of the invention. As described above, the first and second substrates 11, 12 of the LC panel 101 each comprise a polarizer layer rendered on a glass substrate, for example. In the arrangement shown in Fig. 4, the first substrate 11 of the LC panel 101 is composed of a first glass substrate 11a and a first polarizer 11b, and the second substrate 12 is composed of a second glass substrate 12a and a second polarizer 12b. The liquid crystal layer is rendered between the first glass substrate 11a and second glass substrate 12a, the first polarizer 11b is bonded to the surface of the first glass substrate 11a not in contact with the liquid crystal layer (the "outside surface" below), and the second polarizer 12b is bonded to the side of the second glass substrate 12a not in contact with the liquid

crystal layer (the "outside surface" below). The excitation source 30 is thus disposed to the outside surface of the second glass substrate 12a in the edge portion on the opposite side from the connector part of the FPC 16. The second polarizer 12b also does not need to cover the entire outside surface of the second glass substrate 12a, and only needs to cover the effective display area of the liquid crystal panel. By thus not disposing the second polarizer 12b in the area outside the effective display area, the second polarizer 12b is rendered outside of the area of the excitation source 30 as shown in Fig. 4.

Because the polarizer 12b is made from a soft material such as plastic, the mechanical vibrations produced by the excitation source 30 based on an external sound signal will be attenuated if the excitation source 30 is disposed in contact with the polarizer 12b. However, with the arrangement shown in Fig. 4 the excitation source 30 directly causes the hard second glass substrate 12a to flexurally vibrate according to the sound signal, and the sound energy produced by the mechanical vibrations produced by the excitation source 30 are propagated efficiently.

It should be noted that while the polarizer 12b is affixed to the outside surface of the second substrate 12 in the foregoing arrangement, a reflection or phase difference plate may be bonded to the outside surface of the second substrate 12 depending upon the display method (transparent or semi-transparent) of the LCD device. In such arrangements the reflection or phase difference plate is also preferably disposed so as to not cover where the excitation source 30 is disposed. This is because sound energy will not propagate efficiently if the area of the excitation source 30 is covered by the soft sheet-like optical material of the polarizer, reflector, or phase difference plate.

Fig. 5 is a longitudinal section view showing a LCD device according to this embodiment of the invention, and Fig. 6 is a

section view (lateral section view) through line A-A in Fig. 5. Fig. 5 is a section view through line B-B in Fig. 6.

This LCD device 201 is used as a liquid crystal display module in electronic devices such as cell phones and PDAs as noted above, and the main parts of the LCD device 201 include the LC panel 101 and associated light guide plate 20, LED 22, and excitation source 30 (referred to below as the "LCD module"). The frame of the LCD module composes a front bezel 51 and rear bezel 52 each made from metal using a press, for example, and a plastic chassis 54 is fit into the rear bezel 52. The LCD module is supported inside the frame by the chassis 54.

As shown in Fig. 6, the excitation source 30 used to achieve the sound output function (speaker function) in this embodiment of the invention is located on the back side of the second substrate 12 opposite the connector part of the FPC 16 (on the side not in contact with the liquid crystal layer) in the part corresponding to the middle of the connector part. As a result, the LC panel 101 is supported by the chassis 54 at both end portions outside the area of the excitation source 30 (the middle between said end portions) in the edge portions of the second substrate 12 outside the display area on the back side thereof opposite the connector part of the FPC 16. More specifically, thick-walled portions 54a, 54b of the chassis 54 are formed in the parts corresponding to the four corners of the LCD device 201 at both end edge portions of the second substrate 12. Thick-walled portions 54c, 54d are also formed in the other parts of the four corners of the LCD device 201 (the corner areas at the edges on the side where the LED 22 is disposed to the second substrate 12).

In this embodiment of the invention as described above the second substrate 12 of the LC panel is used as the diaphragm for producing sound, the excitation source 30 is disposed in the area on the back of the second substrate 12 opposite the connector part of the FPC 16, that is, in an area where there is available space, and the LED 22 light source is disposed at a position opposite the excitation source 30 with the light

guide plate 20 therebetween. As a result, increase in the external size resulting from adding a excitation source 30 can be suppressed in a transparent or semi-transparent LCD device. More specifically, a sound output function can be added to a LCD device while avoiding an increase in the external size or minimizing any increase in the external size.

Furthermore, because the second substrate 12 of the LC panel is used as the speaker diaphragm in this embodiment of the invention, a separate diaphragm for sound output does not need to be provided in front of the display. There is, therefore, no drop in transmittance resulting from adding a sound output function, and any drop in the image display quality can be avoided.

Furthermore, because the excitation source 30 is disposed on the back of the second substrate 12 in the middle of the connector part of the FPC 16, that is, in the middle of a specific edge portion of the second substrate 12, sound energy from mechanical vibrations produced by the excitation source 30 can be evenly transmitted to the LC panel 101. Yet further, because thick-walled parts of the chassis 54 that supports the LC panel 101 are formed at the four corners of the LCD device 201 in conjunction with the foregoing location of the excitation source 30, a consistent fit can be assured between the chassis 54 and the rear bezel 52 and between the front bezel 51 to the rear bezel 52, and the LC panel 101 can be stably supported and secured. As a result, durability with respect to vibration and impact can be improved in the LCD device 201 and an electronic device comprising the same.

<2. Second embodiment>

Fig. 7 is a side view showing the liquid crystal panel and associated parts in a LCD device according to a second embodiment of the present invention, that is, a side view of the LCD module, and Fig. 8 is a bottom view of the back of this LCD module.

As in the first embodiment, a LC panel 102 according to this embodiment of the invention has a pair of opposing substrates, first substrate 11 and second substrate 121. These substrates are fixed with a specific gap (typically several ten microns) therebetween and have a liquid crystal layer formed by filling this gap between the substrates with a liquid crystal material. This LC panel 102 is also transparent or semi-transparent. Also as in the first embodiment, a FPC 16 for supplying the signals required to display an image to the LC panel 102 is connected to the edge portion of the second substrate 121, and a light guide plate 20 is disposed on the side (the outside surface) of the second substrate 12 that is not in contact with the liquid crystal layer. The excitation source 30 for flexurally vibrating the second substrate 121 to output sound is also disposed in the same position as in the first embodiment (that is, on the back side of the second substrate 121 of the LC panel 101 opposite the connector part of the FPC 16).

In this embodiment, however, the drive circuit generating the drive signal for displaying images on the LC panel 102 is rendered in a semiconductor integrated circuit chip ("IC chip" below), and thus differs from the first embodiment in which the drive circuit is formed integrally with the TFT using a polycrystalline silicon thin film, for example, on the second substrate 12. Space for mounting this IC chip drive circuit (which is mounted as a bare chip) on the second substrate 121 is therefore reserved on the second substrate 121, and the width W (the distance from top to bottom as seen in Fig. 8) of this second substrate 121 is therefore greater than the width of the second substrate 12 in the first embodiment. Using this space, the LED 23 light source is disposed on the back side of the area on the second substrate 121 where the IC chip drive circuit is mounted.

As shown in Fig. 8, the LED 23 in this embodiment is not located opposite the excitation source 30, but instead is located along the side of the light guide plate 20 (the side

along the bottom as seen in Fig. 8) adjacent to the side near which the excitation source 30 is disposed so that light enters the light guide plate 20 from this bottom side edge. Note that if the IC chip drive circuit is mounted along the top side of the 122, the LED 23 is also located along this top edge portion on the back side of the area where the IC chip is disposed to the second substrate 121.

In this embodiment of the invention the second substrate 12 of the LC panel is used as the diaphragm for sound output, the excitation source 30 is disposed to the area on the back of the second substrate 121 opposite the connector part of the FPC 16, that is, where space is available, and the LED 23 light source is disposed along the bottom edge portion of the second substrate 121 in the area on the side opposite where the IC chip is located (see Fig. 8).

As in the first embodiment, a sound output function can thus be added to a transparent or semi-transparent LCD device having an IC chip drive circuit mounted on a substrate of the LC panel while avoiding an increase in the external size or minimizing any increase in the external size.

<3. Third embodiment>

Fig. 10 is a longitudinal section view of a LCD device according to a third embodiment of the present invention. Note that the chassis is omitted in Fig. 10 for simplicity.

As in the first embodiment, this LCD device 203 is also used as a transparent or semi-transparent LCD module in a portable electronic device such a cell phone or PDA, and has a sound output function (speaker function) in addition to an image display function. This sound output function is achieved by the excitation source 30 causing a substrate of the LC panel to flexurally vibrate according to a sound signal.

In this embodiment as shown in Fig. 10, however, the excitation source 30 is disposed to a position from which the excitation source 30 can cause the second substrate 12 of the LC panel to flexurally vibrate and is also mechanically bonded

by an adhesive 41 to the rear bezel 52 so that the excitation source 30 can also cause the rear bezel 52 to flexurally vibrate. Other aspects of the arrangement of this embodiment are the same as in the first embodiment, like parts are identified by like reference numerals, and further description thereof is thus omitted here. However, the FPC 24 whereby the LED 22 is electrically connected is disposed at and near the side of the second substrate 12 instead of as shown in Fig. 1.

In addition to causing the second substrate 12 of the LC panel to flexurally vibrate, the excitation source 30 in the present embodiment thus arranged also causes the rear bezel 52, which is part of the frame of the LCD module, to flexurally vibrate, according to the externally supplied sound signal. The energy used for sound output can thus be efficiently used because the sound energy resulting from the mechanical vibrations produced by the excitation source 30 according to the sound signal is propagated to both the second substrate 12 and the rear bezel 52. As a result, power consumption by the LCD device 203 and an electronic device comprising this LCD device 203 can be reduced while assuring sound output with sufficient volume.

The excitation source 30 is mechanically fixed to the rear bezel 52 by means of adhesive 41 in this third embodiment as described above. However, the height of the thick-walled part of the chassis 54 (not shown in Fig. 10, see Fig. 5) and the height of the rear bezel 52 could instead be adjusted or set appropriately so that the excitation source 30 touches the rear bezel 52, thereby enabling the excitation source 30 to make the rear bezel 52 flexurally vibrate.

<4. Fourth embodiment>

Fig. 11 is a side view showing the liquid crystal panel and associated parts in a LCD device according to a fourth embodiment of the present invention, that is, a side view of the LCD module, and Fig. 12 is a bottom view of the back of this LCD module.

In this embodiment of the invention an excitation source identical to the excitation source 30 in the first embodiment is disposed as a main excitation source 30a in the same location as the excitation source 30 in the first embodiment, and two excitation sources that are smaller than the main excitation source 30a, that is, first complementary excitation source 30b and second complementary excitation source 30c, are also provided. Other aspects of the arrangement of this embodiment are the same as in the first embodiment, like parts are identified by like reference numerals, and further description thereof is thus omitted here. However, the FPC 24 whereby the LED 22 is electrically connected is disposed at and near the side of the second substrate 12 instead of as shown in Fig. 1.

In the arrangement shown in Fig. 11 and Fig. 12, the first and second complementary excitation sources 30b and 30c are disposed on the outside surface of the second substrate 12 on the opposite side of the light guide plate 20 as the main excitation source 30a, but the location of the first and second complementary excitation sources 30b, 30c shall not be so limited. Although the complementary excitation sources 30b, 30c are smaller than the main excitation source 30a in this embodiment, plurality of excitation sources of the same size could be used. The number of excitation sources shall also not be limited to three. This also applies to the other embodiments of the invention. However, for simplicity below we assume that three excitation sources 30a, 30b, 30c of the sizes shown in Fig. 11 and Fig. 12 are disposed to the locations shown in the same figures when the LCD device comprises a plurality of excitation sources.

The same sound signal Ss is input from a source external to the LCD device to the three excitation sources 30a to 30c in this embodiment. As a result, the main excitation source 30a and the complementary excitation sources 30b, 30c also drive the second substrate 12 of the LC panel to flexurally vibrate according to the sound signal Ss. Higher sound output can

therefore be achieved than when only one excitation source is used as in the first embodiment. More specifically, the gain of the sound output to the input sound signal Ss can be improved.

The same sound signal Ss is applied to the three excitation sources 30a to 30c in this embodiment, but different sound signals could be externally applied to these three excitation sources 30a to 30c. Sound from completely different signal sources can thus be output from the excitation sources 30a to 30c, and the function of a sound mixer can thus be rendered in the LC panel. Furthermore, separately controlling the sound signals input to the three excitation sources 30a to 30c makes it possible to achieve stereophonic reproduction and control which part of the LC panel produces sound (this latter arrangement described below as the fifth embodiment).

<5. Fifth embodiment>

As described above, which part of the LC panel produces sound can be controlled by providing a plurality of excitation sources in the LCD device and applying different sound signals to the excitation sources. In this case the LCD device is arranged so that multiple sound signals of different phase and amplitude (level) originating from the same signal source can be input to the plurality of excitation sources, and the phase and amplitude of the sound signals can be controlled. By thus varying the phase and amplitude of the sound signals input to the plurality of excitation sources, the vibrations produced from the plural excitation sources are increased and decreased by mutual interference in the two-dimensional plane of the LC panel. As a result, the strongest sound waves are produced in the air around the position of the strongest vibrations in this two-dimensional plane. This position can be called the "sound output position" of the LC panel, and this sound output position can be controlled by controlling the phase and amplitude of the sound signals. An electronic device having a LCD device with a sound output function thus enabling

controlling the sound output position is described below as a fifth embodiment of the present invention.

Fig. 13 is a side view showing the liquid crystal panel and associated parts in a LCD device used in an electronic device according to the present embodiment, that is, Fig. 13 is a side view of the LCD module in this embodiment of the invention. Fig. 14 is a bottom view showing the back of this LCD module, and Fig. 15 is a function block diagram showing the main components of an electronic device according to this embodiment of the invention. Note that the light guide plate 20 is omitted from Fig. 14 for simplicity of description.

As shown in Fig. 15, an electronic device 305 according to this embodiment of the invention has a LCD module 205, a LCD controller 402 for supplying image signal Sv to this LCD module 205 and controlling image display on the LCD module 205, a signal processing circuit 403 for outputting signals S1 to S3 of the sound to be produced using the sound output function of the LCD module 205, and a microcomputer for supplying digital image data to the LCD controller 402 and supplying sound data Ssd to the signal processing circuit 403.

The LCD device shown in Fig. 13 and Fig. 14 is used as the LCD module 205 of the electronic device 305 arranged as described above, and the different sound signals S1 to S3 are supplied to the three excitation sources 30a to 30c from a signal processing circuit 403 external to the LCD device. Other aspects of the arrangement of this embodiment are the same as in the fourth embodiment shown in Fig. 11 and Fig. 12, like parts are thus identified by like reference numerals, and further description thereof is omitted here.

In this embodiment of the invention the LCD controller 402 supplies image signal Sv to the LCD module 205 based on data supplied from the microcomputer 401. In the LCD module (LCD device) 205, this image signal Sv is applied through the FPC 16 to the LC panel 101, and the LC panel 101 thus presents the image represented by the image signal Sv. The LCD module 205 can also output sound in parallel with this image display. More

specifically, based on data Dp from an input device or other device in the electronic device 305, the microcomputer 401 applies a signal Sp (the "sound position signal" below) denoting the sound output position in the (image display surface of the) LC panel 101 to the signal processing circuit 403 together with the sound data Ssd.

The signal processing circuit 403 generates an analog sound signal by D/A conversion of this sound data Ssd and varies the phase and amplitude of this sound signal based on the sound position signal Sp, thereby generating three different sound signals S1 to S3 of mutually different phase and amplitude and supplying these sound signals S1 to S3 to the LCD module 205.

In the LCD module 205 these sound signals S1 to S3 are applied to the excitation sources 30a to 30c, respectively. The excitation sources 30a to 30c then cause the second substrate 12 of the LC panel to vibrate at their respective locations according to the sound signals S1 to S3 applied thereto. As a result, flexural vibrations produced from the locations of the excitation sources 30a to 30c travel through the second substrate 12, and the vibrations interfere with each other on the second substrate, thereby determining the location of the strongest vibrations on the outside surface of the second substrate 12. This means that the sound output position is determined by the differences in phase and amplitude between the sound signals S1 to S3. That is, the sound output position in the outside surface of the second substrate 12, that is, the sound output position of the LC panel, can be controlled by using the signal processing circuit 403 to control the phase and amplitude of the sound signals S1 to S3 according to the sound position signal Sp.

<6. Sixth embodiment>

Images displayed on the LC panel can be linked to the sound output position of the LC panel in the foregoing fifth embodiment of the invention by controlling the phase and

amplitude of the sound signals S1 to S3 according to the image displayed on the LC panel based on the image signal Sv. An electronic device comprising this type of LCD module is described next below as a sixth embodiment of the invention.

Fig. 16 is a plan view showing the liquid crystal panel and associated parts in a LCD device used in an electronic device according to this embodiment of the present invention, that is, a plan view as seen from the front of the LCD module in this embodiment of the invention, and Fig. 17 is a function block diagram showing the main parts in an electronic device according to this embodiment of the invention.

As shown in Fig. 17, the hardware configuration of an electronic device 306 according to this embodiment of the invention is basically the same as that of the fifth embodiment shown in Fig. 15, like parts are therefore identified by like reference numerals, and further description thereof is omitted here. In this embodiment the microcomputer 401 receives data (referred to as "combined data" below) Dvs combining the image data with position data from an input device or other device inside the electronic device 306. This combined data Dvs represents the image to be displayed on the LCD module 205 and contains data denoting the sound output position in the displayed image as tag information. MPEG-7, for example, provides a structural framework for adding this sound output position to image data.

When the microcomputer 401 receives this combined data Dvs, the microcomputer 401 separates the image data Svd from the combined data Dvs and applies the image data Svd to the LCD controller 402 based on a program stored in memory in the microcomputer 401. Based on this image data Svd the LCD controller 402 supplies the image signal Sv to the LCD module 205. The LCD module (LCD device) 205 then presents the image represented by the image signal Sv on the LC panel 101. Based on the same program, the microcomputer 401 also extracts the position data from the combined data Dvs and generates sound position signal Sp, supplies this signal to the signal

processing circuit 403 and also supplies the sound data Ssd to the signal processing circuit 403. The signal processing circuit 403 acquires an analog sound signal by D/A converting the sound data Ssd and varies the phase and amplitude of this sound signal based on the sound position signal Sp to generate three sound signals S1 to S3 of mutually different phase and amplitude, and supplies these sound signals S1 to S3 to the LCD module 205. The excitation sources 30a to 30c of the LCD module 205 then cause the second substrate 12 of the LC panel to vibrate at their respective positions based on the sound signals S1 to S3 applied thereto. As a result, the sound represented by the sound data Ssd is produced at the locations in the image presented on the LC panel indicated by the position data in the combined data Dvs input to the microcomputer 401 based on the same principle described in the foregoing fifth embodiment.

In addition to linking a displayed image with the output sound, this embodiment of the invention can thus also link where sound is produced in the LC panel to the image displayed on the LC panel. As a result, the image of a monster, for example, can be displayed on the LC panel and sound can be output from the actual position corresponding to the monster's mouth in the usable display area 10a of the LC panel as shown in Fig. 16.

Position data denoting the sound output position in a displayed image is provided together with the image data representing the image to be displayed in this embodiment of the invention as described above. Alternatively, however, the sound output position in the image to be displayed can be detected by receiving only the image data and detecting movement in the objects, people, or animals represented in the image data, or by applying an image recognition or image understanding process to the received image data. In this situation the sound position signal Sp applied to the signal processing circuit 403 is generated according to the detection result.

<7. Seventh embodiment>

Fig. 18 is a side view showing the liquid crystal panel and associated parts in a LCD device according to a seventh embodiment of the present invention. The LC panel 107 in this LCD device has a pair of opposing substrates, first substrate 13 and second substrate 14, fixed with a specific gap (typically several microns) therebetween, and a liquid crystal material is filled between these substrates to form a liquid crystal layer. This LC panel 107 is reflective, that is, the first substrate 13 is transparent but a reflective layer is formed over the electrodes on the side of the second substrate 14 in contact with the liquid crystal layer. The light guide plate 20 is then disposed covering the usable display area on the outside surface of the first substrate 13, and the LED 22 light source and excitation source 30 are disposed in two opposing edge portions of the first substrate 13 with the light guide plate 20 therebetween. Other aspects of the arrangement of this embodiment are the same as in the first embodiment, like parts are identified by like reference numerals, and further description thereof is thus omitted here. Note that the excitation source 30 is disposed to an edge portion of the first substrate 13 in the example shown in Fig. 18, but could be disposed to an edge portion of the second substrate 14 as shown in Fig. 19.

Thus comprised, the excitation source 30 causes the first substrate 13 to flexurally vibrate according to an external sound signal, thereby causing the LC panel 107 to produce sound, and enabling a substrate of the LC panel to be used as a diaphragm for sound output. Furthermore, by disposing the LED 22 light source and excitation source 30 on opposite sides of the light guide plate 20 at positions corresponding to edge portions outside the effective display area of the LC panel, a sound output function can be achieved in a reflective LCD device with a front light unit while suppressing any increase in the external size.

<8. Eighth embodiment>

Fig. 20 is a longitudinal section view showing a LCD device according to an eighth embodiment of the present invention. The chassis is omitted from Fig. 20 for simplicity. The frame of a LCD device according to this eighth embodiment of the invention is the same as in the third embodiment, and the arrangement of the LC panel according to this eighth embodiment is the same as in the seventh embodiment. Like parts are therefore identified by like reference numerals, and further description thereof is thus omitted here. Furthermore, as in the third embodiment, the excitation source 30 in this LCD device 207 is located where the excitation source 30 can cause the LC panel to flexurally vibrate, and is also mechanically connected to the front bezel 51 through an intervening structural panel 15 by means of adhesive 41.

In this embodiment of the invention the excitation source 30 causes the structural panel 15 located at the surface of the LCD module and the front bezel 51 that is part of the case to flexurally vibrate according to an external sound signal. Examples of this structural panel 15 include a complementary display panel 15a presenting representations of functions or operating controls of an electronic device comprising this LCD device 207 as a LCD module as shown in Fig. 21, and a surface panel 15b such as a touch panel having a sensor function enabling use as an operating panel. (Note that if the structural panel 15 is a touch panel, the structural panel 15 does not need to cover the entire surface of the LC panel.) The structural panel 15 is one structural part of the LCD device 207. As in the third embodiment, disposing the excitation source 30 between the LC panel and structural panel 15 thus enables the entire module to efficiently use the sound energy generated by the mechanical vibrations produced by the excitation source 30 according to the supplied sound signal. Power consumption by the LCD device 207 and an electronic

device comprising the LCD device 207 can thus be reduced while assuring sufficient sound volume.

The excitation source 30 is mechanically bonded to the structural panel 15 by means of adhesive 41 in the example shown in Fig. 20. However, the height of the thick-walled part of the chassis (not shown in Fig. 20) and the height of the bezel 51 could instead be adjusted or set appropriately so that the excitation source 30 touches the structural panel 15, thereby enabling the excitation source 30 to make the structural panel 15 and bezel 51 flexurally vibrate.

Furthermore, if the structural panel 15 is a complementary display panel such as a touch panel providing an operating unit for the electronic device, the excitation source 30 can also be driven to produce specific vibration patterns for each function displayed graphically on the structural panel 15. In this situation a vibration pattern (the vibration waveform, amplitude, frequency, or combination thereof) is predefined for each function that can be performed by operating the operating panel of the electronic device, that is, a specific vibration pattern is linked to each operation used to execute a specific function. In addition, an operation-dependent signal generating means that generates a signal causing the excitation source 30 to vibrate according to the vibration pattern corresponding to the executed operation, and supplies this signal in place of the above-described sound signal to the excitation source 30 when the operator then performs an operation, is rendered in the electronic device or LCD module. Improper operation of the device can thus be reduced with this arrangement because the specific vibration patterns thus generated can make the user aware of the result of a particular operation.

When the structural panel 15 is a display panel 15a or surface panel 15b having a sensor function enabling use as an operating unit as shown in Fig. 21, rendering this operation-dependent signal generating means in the LCD module (LCD device) enables the LCD device itself to cause the excitation source to produce vibrations triggered by a specific operation.

In the arrangement of the present embodiment shown in Fig. 20 the light guide plate 20 is disposed to the display surface side of the LC panel, and the structural panel 15 is disposed between the light guide plate 20 and the bezel 51 with one side of the structural panel 15 in contact with the inside surface of the bezel 51. The invention shall not be limited to this arrangement, however. In a transparent LCD device having the light guide plate 20 disposed on the back side of the LC panel (that is, the opposite side as the display surface), the structural panel 15 can be disposed between the LC panel and bezel 51 with one side of the structural panel 15 in contact with the inside wall of the bezel 51. In addition to the above-noted display panel 15a and surface panel 15b, the structural panel 15 could be a display panel that has a display function but does not have a sensor function enabling operations (process selection). In this case a sensor function enabling operation is achieved by making a selection using a separately provided jog wheel or buttons, for example. If a jog wheel is used an indicator denoting the selection can be simply displayed on the LC panel beside the proper items displayed on the structural panel 15. A means for generating vibrations corresponding to the selection (that is, an excitation source and means for generating the signal supplied to the excitation source) can also be rendered in the LCD module in this case.

<9. Ninth embodiment>

Fig. 22 is a longitudinal section view showing the arrangement of a LCD device according to a ninth embodiment of the present invention. The chassis is omitted from Fig. 22 for simplicity. The frame of a LCD device according to this ninth embodiment of the invention is the same as in the third embodiment, and the arrangement of the LC panel according to this ninth embodiment is the same as in the seventh embodiment. Like parts are therefore identified by like reference numerals, and further description thereof is thus omitted here. Unlike in the third embodiment, the excitation source 30 in this LCD

device 210 is separated from the LC panel by an intervening buffer material 17a, and vibrations produced by the excitation source 30 are dampened or cancelled by this buffer material 17a.

This buffer material 17a could be a spongy material such as Poron(R) high-density urethane foam, or a gel material injected between the excitation source 30 and LC panel. Because the expected vibration stress and amplitude applied to the excitation source 30 are determined by the desired volume of the output sound, the hardness of this sponge material or the viscosity of the gel can be appropriately adjusted according to these expected values when the buffer material 17a is thus provided. Depending upon the hardness of the sponge and the viscosity of the gel, this buffer material 17a also works to secure the excitation source 30 inside the LCD module, thereby helping to improve durability in mobile environments where the device is easily subjected to external stress. The excitation source 30 can be disposed so that the excitation source 30 does not contact the second substrate 12 of the LC panel and leaves a space therebetween. In this arrangement the buffer material 17a can be treated as being an imaginary air-filled construction, which thus works to block the transmission of sound vibrations to the LC panel. When the buffer material 17a is thus space, the propagation of vibrations can be substantially completely stopped. A LCD module according to this embodiment of the invention is thus suited to applications that are averse to stress applied to the LC panel surface or to an operating position of a touch sensor in contact with the LC panel surface. An active anti-vibration element that inverts the signal input to the excitation source 30, applies a suitable coefficient, and operates according to resulting signal could also be used.

As in the third embodiment the excitation source 30 is mechanically coupled to the bezel 52 by an adhesive 41. Propagation of sound vibrations generated by the excitation source 30 to the LC panel is suppressed as described above, the energy of those sound vibrations is transmitted to the bezel

(frame) 52 to which the excitation source 30 is bonded, and the bezel 52 is thus caused to flexurally vibrate. When the LCD module (LCD device) according to this embodiment of the invention is used alone or used where nothing is externally attached thereto, the flexural vibration of the bezel 52 is emitted directly into the air, and the sound vibrations thus reach the user. Even when this LCD module is used in an electronic device such that the LCD module is enclosed by some outer packaging, the bezel 51 or 52 is fixed to the frame of the electronic device. As a result, sound vibrations from the excitation source 30 are transmitted to the outside through the connecting members fastening the LCD module, and thus reach the user.

An effective audio design can also be expected because the resonance effect of the cavity inside the electronic device can also be used. More particularly, projecting sound only from the front is not always desirable in portable devices that are not used in a fixed location, as are stationary devices, and for which small size and low weight are essential. In addition, when the device is portable and is held by some part of the body, such as in the hand, while moving, vibrations emitted from the outside case of the device can also be transmitted directly to the user's body, including by bodysonics and bone conduction, and the energy consumed for sound output can therefore be used even more efficiently.

Sound vibrations passing from the excitation source 30 through the rear bezel 52 can also be transmitted through the front bezel 51 and the like to the substrates 11, 12 of the LC panel. Five different types of LCD modules arranged to address this are described next below as second to sixth variations of the present embodiment.

More specifically, in the second variation of this embodiment (LCD device 211) shown in Fig. 23 a buffer material 17b is disposed between the front bezel 51 and the first substrate 11 of the LC panel, thereby blocking propagation of sound vibrations from the front bezel 51 to the LC panel.

In the third variation (LCD device 212) of this embodiment shown in Fig. 24, a buffer material 17c is disposed between the rear bezel 52 and light guide plate 20 to block vibrations from travelling from the rear bezel 52 through the light guide plate 20 to the LC panel, and propagation of sound vibrations from the rear bezel 52 to the LC panel is thereby prevented.

In the fourth variation (LCD device 213) of this embodiment shown in Fig. 25, a buffer material 17d is disposed between the light guide plate 20 and the second substrate 12 of the LC panel, thereby blocking the propagation of sound vibrations through the path from the rear bezel 52 to the LC panel by way of the intervening light guide plate 20.

In the fifth variation (LCD device 214) of this embodiment shown in Fig. 26, which corresponds to a section view through line B-B in Fig. 6, a buffer material 17e is disposed between the chassis 54 and the second substrate 12 of the LC panel, thereby blocking the propagation of sound vibrations through the path from the rear bezel 52 to the LC panel by way of the intervening chassis 54.

In the sixth variation (LCD device 215) of this embodiment shown in Fig. 27, which corresponds to a section view through line B-B in Fig. 6, a buffer material 17f is disposed between the chassis 54 and the rear bezel 52 part of the frame. As a result, the chassis 54 can be disposed in contact with the LC panel while both can be freely supported, and the propagation of sound vibrations through the path from the rear bezel 52 to the LC panel by way of the intervening chassis 54 can be blocked while the chassis 54 continues to hold the LC panel fixed.

Note that the same materials and configuration used for the above-described buffer material 17a can be used for the buffer materials 17b to 17f in the foregoing second to sixth variations. Note, further, that the arrangement of the present embodiment can use any combination of the foregoing second to sixth arrangements shown in Fig. 23 to Fig. 27.

In the LCD modules according to this embodiment of the invention the location of the excitation source 30 is moved (offset) only slightly towards the rear bezel 52 from the second substrate 12 of the LC panel in comparison with the arrangement of the first embodiment (shown in Fig. 1), and the relative positions of the light source and sound source can thus remain the same as in the first embodiment. This embodiment of the invention thus yields the same effects as the first embodiment described above, including suppressing any increase in the external size.

As described above, the bezel 52 of the LCD module is used as the diaphragm for sound output in this embodiment of the invention, the excitation source 30 is disposed in the area where space is available on the back side of the connector part of the FPC 16, and the light source 22 is disposed at a position opposite the excitation source 30 with the light guide plate 20 therebetween. The LC panel is also separated from the transmission of sound vibrations by a space or buffer material 17a to 17d. A sound output function can therefore be achieved in a LCD module according to this embodiment of the invention while suppressing increase in the external size and avoiding any effect on the display even in cases in which the display could be affected by vibration of the display surface.

<10. Tenth embodiment>

Fig. 28 is a bottom view showing the liquid crystal panel and associated parts in a LCD device according to a tenth embodiment of the present invention, that is, a bottom view of the back of the LCD module in this embodiment. This LCD device has a pickup 35 for converting mechanical vibrations to an electric signal in place of the excitation source 30 for achieving a sound output function. Other aspects of the arrangement of this embodiment are the same as in the first embodiment, like parts are identified by like reference numerals, and further description thereof is thus omitted here. However, the FPC 24 whereby the LED 22 is electrically

connected is disposed at and near the side of the second substrate 12 instead of as shown in Fig. 1. This pickup 35 could be manufactured using a piezoelectric element made from quartz, Rochelle salt crystals, or a ceramic thin plate.

When sound waves passing through the air around the LCD device are picked up and cause the second substrate 12 to vibrate in this embodiment of the invention, the pickup 35 disposed to the outside surface of the second substrate 12 converts those vibrations to an electric signal, which is output as a sound signal externally to the LCD device (another device inside the electronic device using the LCD device). A sound input function (microphone function) is thus achieved in this LCD device.

In this embodiment of the invention the pickup 35 is disposed to the area on the back of the second substrate 12 opposite the connector part of the FPC 16, that is, where space is available, and the LED 22 light source is disposed at a position opposite the pickup 35 with the light guide plate 20 therebetween. As a result, a sound input function can thus be added to a transparent or semi-transparent LCD device while minimizing any increase in the external size.

<11. Eleventh embodiment>

Fig. 29 is a bottom view showing the liquid crystal panel and associated parts in a LCD device according to an eleventh embodiment of the present invention, that is, a bottom view of the back of the LCD module in this embodiment of the invention. This LCD device has both an excitation source 30b for achieving a sound output function (speaker function) and a pickup 35b for converting mechanical vibrations to electric signals.

In the arrangement shown in Fig. 29 the excitation source 30b and pickup 35b are both disposed at the position where the excitation source 30 is located in the first embodiment, that is, at a position on the back of the second substrate 12 of the LC panel opposite the connector part of the FPC 16. Other aspects of the arrangement of this embodiment are the same as

in the first embodiment, like parts are identified by like reference numerals, and further description thereof is thus omitted here. However, the FPC 24 whereby the LED 22 is electrically connected is disposed at and near the side of the second substrate 12 instead of as shown in Fig. 1. Note that the relative positions of the excitation source and pickup shall not be limited to the arrangement shown in Fig. 29. Furthermore, the excitation source 30b and pickup 35b are longitudinally aligned in Fig. 29, but a long, narrow excitation source and pickup could be arranged side by side. A plurality of excitation sources or a plurality of pickups could also be provided.

With this embodiment of the invention the excitation source 30b and pickup 35b are disposed to the area on the back of the second substrate 12 opposite the connector part of the FPC 16, that is, where space is available, and the LED 22 light source is disposed at a position opposite the excitation source 30b and the pickup 35b with the light guide plate 20 therebetween. As a result, a sound output function and a sound input function can thus be added to a transparent or semi-transparent LCD device while minimizing any increase in the external size.

It should be noted that the second substrate 12 of the LC panel is used by both the excitation source 30b and pickup 35b in the present embodiment. As a result, if the sound output function and sound input function are used at the same time, the vibrations of the second substrate 12 for projecting sound waves from the second substrate 12 into the surrounding air will also be converted to electric signals by the pickup 35b. The electric signals generated by the pickup 35b will thus contain signals for both the sound to be input and the sound to be output. However, this problem can be avoided by an arrangement that, for example, generates an opposite phase signal of the sound signal to be supplied to the excitation source 30b, adds this opposite phase signal to the electric signal output from the pickup 35b, and thereby cancels the

signal component representing the audio output in the converted electric signal.

<12. Variation>

In the foregoing fifth and sixth embodiments that are arranged to control the position from which sound is produced from the LC panel, a signal processing circuit 403 is used to adjust the phase and amplitude of the sound signals S1 to S3 to be supplied to the excitation sources 30a to 30c, and this signal processing circuit 403 is disposed externally to the LCD device (see Fig. 15, Fig. 17). The signal processing circuit 403 could, however, be disposed inside the LCD device (LCD module 205).

Furthermore, the signal processing circuit 403 adjusts the phase and amplitude of the sound signals S1 to S3 by analog signal processing, but digital signal processing could be used. Further alternatively, this signal processing could be handled in software by the microcomputer 401 or a digital signal processor (DSP).

INDUSTRIAL APPLICABILITY

The present invention can be used in any type of electronic device having a liquid crystal display device and in a liquid crystal display device used in such electronic devices, and is particularly well suited to use in a liquid crystal display module used in such portable devices as cell phones and PDAs.